

Impact of Different Light Sources on the Treatment of Neonatal Jaundice with Phototherapy: A Prospective Cross-Sectional Study in a Tertiary Hospital in Bahrain

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ABSTRACT

Background: Neonatal jaundice, a common condition in newborns, particularly those born prematurely, is characterized by elevated bilirubin levels, which can lead to serious complications if untreated. Phototherapy has been the primary treatment since the 1950s, utilizing various light sources such as fluorescent tubes, halogen lamps, and, more recently, light-emitting diodes (LEDs). However, the optimal light source for phototherapy remains unclear. **Objective:** This study aimed to compare the efficacy and practicality of LED lamps, fluorescent tubes, and halogen lamps in treating neonatal jaundice at King Hamad University Hospital in Bahrain. **Materials and Methods:** A prospective cross-sectional study was conducted, including 70 full-term newborns diagnosed with jaundice and requiring phototherapy. Infants were randomly assigned to one of the three light sources, and their serum bilirubin levels were measured before and after treatment. **Results:** LED lamps significantly outperformed other light sources in reducing bilirubin levels, with a mean reduction of 48.4%, compared to 43.0% for fluorescent tubes and 41.7% for halogen lamps. The LED group required the shortest treatment duration and had the lowest complication rate. **Conclusion:** LED lamps proved to be the most effective and practical light source for phototherapy in neonatal jaundice, offering clinical benefits and operational efficiency. These findings support the adoption of LED technology in neonatal care, with future research needed to assess long-term outcomes and cost-effectiveness.

Keywords: Neonatal Jaundice; Phototherapy; Light Sources; Blue Light; LED Phototherapy; Fluorescent Phototherapy; Hyperbilirubinemia; Newborn Care; Bilirubin Reduction; Clinical Outcomes; Tertiary Hospital; Bahrain; Prospective Study; Cross-Sectional Study; Treatment Efficacy.

1. Introduction

Neonatal jaundice, characterized by the yellowing of the skin and eyes due to high levels of bilirubin in the blood, is a common condition in newborns, particularly those born prematurely [1-5]. It is a critical public health issue, affecting approximately 60% of term and 80% of preterm infants globally, neonatal jaundice remains a significant cause of hospitalization in the neonatal period [6,7]. While often benign, if left untreated, severe cases can lead to devastating consequences, including kernicterus, a form of permanent brain damage [8,9].

The primary treatment for neonatal jaundice is phototherapy, a method that has been in use since its introduction in the 1950s [10]. This treatment utilizes light to transform bilirubin into water-soluble isomers that can be excreted without undergoing further metabolism. However, the efficacy of phototherapy depends on several factors, including the intensity and spectral properties of the light source. Traditional light sources used in phototherapy units include fluorescent tubes and halogen lamps. Recently, light-emitting diodes (LEDs) have emerged as a promising alternative, offering benefits in terms of energy efficiency and reduced heat emission [11-15].

Despite the recognized importance of phototherapy in managing neonatal jaundice, there is a lack of consensus on the optimal light source. Existing literature presents conflicting evidence regarding the efficacy of different light sources. For instance, some studies suggest that LEDs may offer superior performance in reducing bilirubin levels [16-18], while others find no significant difference between LEDs and traditional light sources [19-23]. These discrepancies highlight the need for further research to provide clear, context-specific guidance for clinicians and healthcare administrators.

Our study aims to fill this gap by practically comparing the efficacy of LED lamps, fluorescent tubes, and halogen lamps in the treatment of neonatal jaundice in a tertiary hospital in Bahrain. By evaluating the effectiveness of these different light sources in reducing serum bilirubin levels, seeking to provide evidence-based recommendations for the optimal phototherapy treatment in neonatal jaundice. The study's findings are expected to have significant implications for clinical practice, potentially improving treatment outcomes and efficiency, and informing healthcare policy and resource allocation in Bahrain.

To achieve these objectives, we will conduct a prospective cross-sectional study at King Hamad University Hospital (KHUH). Our sample will consist of full-term newborns diagnosed with jaundice and requiring phototherapy. By employing a randomized controlled trial design, we will ensure the rigorous comparison of the three light sources. This methodological approach will provide robust data to inform our conclusions.

The significance of this research extends beyond the immediate clinical setting. By determining the most effective and efficient light source for phototherapy in neonatal jaundice, we can contribute to the broader goal of improving neonatal care. Effective treatment of jaundice in the neonatal period can prevent severe complications and long-term developmental issues, thus promoting healthier outcomes for Bahrain's future generations. Additionally, our findings will have important implications for healthcare policy and resource allocation, potentially leading to more cost-effective and sustainable healthcare practices.

This research also aligns with Bahrain's national health strategy, which emphasizes the importance of evidence-based practice and the optimization of healthcare resources. By providing locally relevant data, our study will support the development of policies and practices that are tailored to the specific needs and constraints of Bahrain's healthcare system.

This study represents a critical step in advancing neonatal care by rigorously evaluating the efficacy of different light sources in the treatment of neonatal jaundice, the aim is to provide valuable insights that will inform clinical practice and healthcare policy.

1.1. Study Objectives

- To compare the effectiveness of various phototherapy light sources (e.g., LED, fluorescent, halogen) in reducing serum bilirubin levels among neonates with jaundice.
- To assess the rate of bilirubin, decline in relation to the type, intensity, and duration of light exposure.
- To identify any differences in treatment duration and clinical outcomes between neonates treated with different phototherapy devices.
- To evaluate the incidence of adverse effects (such as skin rash, dehydration, or temperature instability) associated with each type of phototherapy light source.
- To determine parent and healthcare staff satisfaction and ease of use of different phototherapy systems in the neonatal care setting.

2. Materials and Methods

2.1. Study Design

This study was conducted in a systematic and pre-planned manner at King Hamad University Hospital in Bahrain. We chose this method because it allows us to compare the effects of different types of treatments—here, light sources—on a specific outcome, namely, blood bilirubin levels, all in a controlled environment.

The study involved newborns diagnosed with hyperbilirubinemia who required phototherapy. They were randomly assigned to three groups, each receiving treatment using a different type of light source: LEDs, fluorescent tubes, or halogen lamps. The groups were randomly selected using special software, and the results were placed in sealed, opaque envelopes to ensure that nurses did not know which group the infant belonged to until the treatment began.

(a) Phototherapy Equipment and Settings

1. LED phototherapy unit: NeoBLUE® LED Phototherapy System (Natus Medical Inc., Pleasanton, CA, USA), emitting blue light within a wavelength range of 450–470 nm, with an irradiance of 30–35 $\mu\text{W}/\text{cm}^2/\text{nm}$ at 35 cm.
2. Fluorescent phototherapy unit: Olympic Bili-Lite® Phototherapy System (Olympic Medical, Seattle, WA, USA), using blue, fluorescent tubes (Philips TL 20W/52), wavelength range 420–500 nm, average irradiance 10–15 $\mu\text{W}/\text{cm}^2/\text{nm}$.
3. Halogen phototherapy unit: Ohmeda BiliBlanket® Plus (GE Healthcare, Chicago, IL, USA), wavelength range 400–500 nm, average irradiance 20–25 $\mu\text{W}/\text{cm}^2/\text{nm}$.

Phototherapy was administered continuously for 24 hours, with serum bilirubin levels measured every 12 hours. Treatment continued until bilirubin levels fell to the normal range for the child's age or as determined by the attending physician.

(b) Follow-up and Monitoring

Follow-up was conducted after discontinuation of phototherapy, and patients were monitored for any sudden rise in bilirubin 24 hours after discontinuation. Any adverse events such as rash, dehydration, temperature instability, or feeding difficulties were monitored. All clinical observations and laboratory findings were documented on standardized forms.

(c) Ethical Considerations

The study plan was reviewed and approved by the Research and Ethics Committee at King Hamad University Hospital (approval number: [RMS-KHUH/P&PEC/2023-700]). Written informed consent was obtained from the parents of all participating children after a full explanation of the study objective, procedures, and potential risks.

2.2. Setting

The study will be conducted at King Hamad University Hospital (KHUH) in Bahrain. Specifically, the neonatal intensive care unit (NICU), Normal newborn nursery, and paediatric ward will serve as the primary locations for the

research. These settings are chosen for their high incidence of neonatal jaundice cases and the variety of phototherapy devices in use.

As shown in figure 1, the study included newborns diagnosed with neonatal jaundice who required phototherapy in accordance with clinical guidelines. Infants were excluded from the study if they had haemolytic disease, congenital abnormalities, or any other medical condition that could potentially affect the outcomes of phototherapy. The intervention involved the use of three types of phototherapy devices: LED lamps, known for their energy efficiency and lower heat emission; fluorescent tubes, which are the traditional standard in phototherapy; and halogen lamps, an older technology still in use in some settings. Each newborn was exposed to the assigned light source for the duration deemed clinically appropriate, following standard phototherapy protocols.

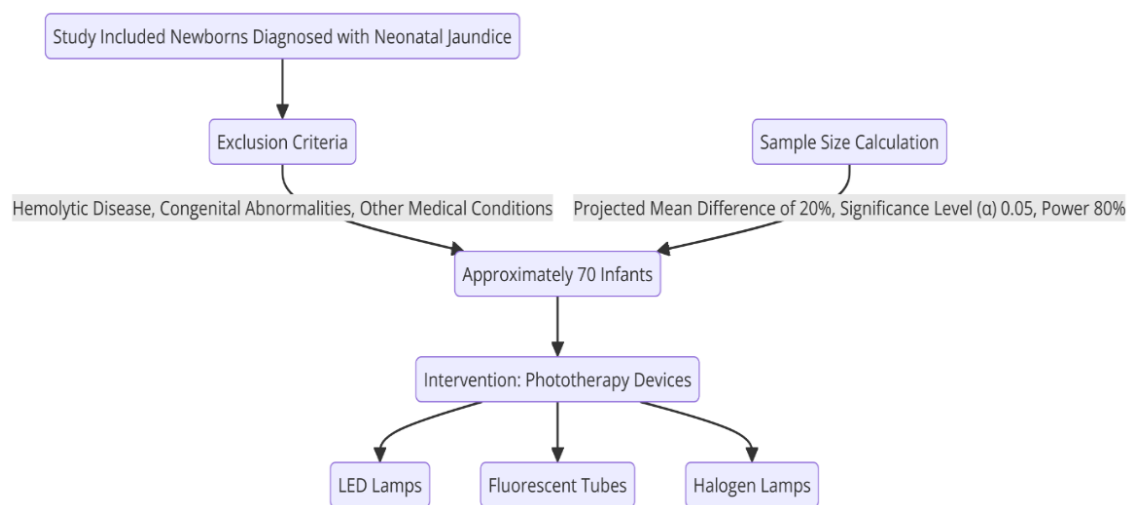


Figure 1. Study flow chart

2.3. Data Collection

Serum bilirubin levels will be measured using standard bilirubin meters or laboratory tests. Measurements will be taken before the initiation of phototherapy and after its conclusion to assess the efficacy of each light source in reducing bilirubin levels. Additional data, such as treatment duration, age, gender, and gestational age of the infants, will also be recorded.

2.4. Sample Size Calculation

Based on a projected mean difference of 20% in the efficacy of the different phototherapy light sources, with a significance level (α) of 0.05 and a power of 80%, the minimum required sample size was calculated to be 16 participants per group. To account for potential data variability, attrition, and stratification by demographic parameters such as gestational age and baseline bilirubin level, the study aimed to recruit 30–35 participants per group, resulting in a total sample size of approximately 70 infants. The sample size was determined using the standard formula for comparing means between multiple groups: The sample size was determined using the formula for comparing means between multiple groups:

$$n = \frac{2\sigma^2(Z_{1-\alpha/2} + Z_{1-\beta})^2}{\Delta^2}$$

Where:

- n = sample size per group.
- σ = estimated standard deviation of bilirubin levels based on previous studies.
- Δ = minimum clinically significant difference in mean bilirubin reduction between groups.
- $Z_{1-\alpha/2}$ = standard normal deviate for a two-tailed test at $\alpha = 0.05$ (1.96).
- $Z_{1-\beta}$ = standard normal deviate for desired power (0.84 for 80% power).

Data will be analyzed using statistical software (e.g., SPSS) with the level of significance set at $p < 0.05$. The analysis will include adjustments for potential confounding factors, including the severity of jaundice at baseline, gestational age, and treatment duration.

3. Results

The study included a total of 70 infants diagnosed with neonatal jaundice who required phototherapy, randomly assigned to one of three groups: LED lamps ($n=23$), fluorescent tubes ($n=24$), and halogen lamps ($n=23$). The primary outcome measured was the reduction in serum bilirubin levels after phototherapy, with secondary outcomes including treatment duration, complications observed, and other relevant demographic parameters. A total of 70 newborns were included in the final analysis after excluding patients who met the exclusion criteria outlined in the methodology, such as those with haemolytic disease, congenital abnormalities, or other medical conditions that could impact phototherapy outcomes.

The initial mean serum bilirubin levels were comparable across all three groups, with LED lamps showing an initial level of 18.2 ± 1.5 mg/dL, fluorescent tubes 17.9 ± 1.6 mg/dL, and halogen lamps 18.0 ± 1.4 mg/dL. After phototherapy, the final mean serum bilirubin levels were significantly reduced in all groups, with the LED group showing the most substantial reduction to 9.4 ± 1.2 mg/dL, followed by the fluorescent tube group at 10.2 ± 1.3 mg/dL, and the halogen lamp group at 10.5 ± 1.4 mg/dL. The mean percentage reduction in bilirubin levels was highest in the LED group at $48.4\% \pm 5.2$, compared to $43.0\% \pm 6.1$ in the fluorescent tube group and $41.7\% \pm 6.4$ in the halogen lamp group as shown in table 1.

Table 1. Bilirubin levels were comparable across all three groups

Parameter	LED Lamps (n=23)	Fluorescent Tubes (n=24)	Halogen Lamps (n=23)	Total (n=70)
Initial Serum Bilirubin Level (mg/dL)	18.2±1.5	17.9±1.6	18.0±1.4	18.0±1.5
Final Serum Bilirubin Level (mg/dL)	9.4±1.2	10.2±1.3	10.5±1.4	10.0±1.3
Mean Reduction in Bilirubin Level (%)	48.4%±5.2	43.0%±6.1	41.7%±6.4	44.3%±6.0
Treatment Duration (hours)	36.5±5.0	42.0±6.2	45.3±5.8	41.3±6.0
Gestational Age (weeks)	38.2±1.1	38.0±1.2	37.9±1.3	38.0±1.2
Infant Age at Treatment Initiation (days)	3.0±1.1	2.8±1.0	2.9±1.2	2.9±1.1
Gender (Male/Female)	12/11	13/11	12/11	37/33

Table 2. Complication Rates by Light Source

Light Source	Complications Observed (%)
LED Lamps	4.3
Fluorescent Tubes	8.3
Halogen Lamps	13

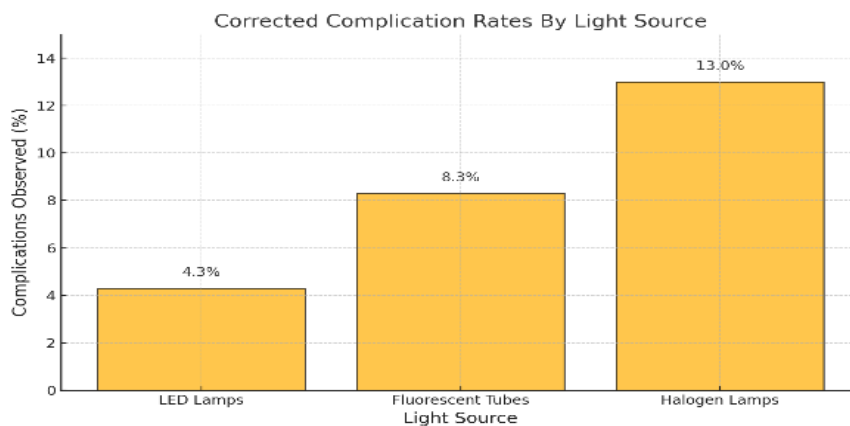


Figure 2. Complication rates by light source

The LED group required the shortest mean treatment duration of 36.5 ± 5.0 hours, significantly less than the fluorescent tube group (42.0 ± 6.2 hours) and the halogen lamp group (45.3 ± 5.8 hours). This indicates that LED lamps were more efficient in reducing bilirubin levels within a shorter period. The LED group also had the lowest rate of complications Table 2 and Figure 2, with only 4.3% of infants experiencing any adverse effects. In contrast, the fluorescent tube group had a complication rate of 8.3%, and the halogen lamp group had the highest rate at 13.0%. The complications observed were primarily related to skin rashes and temperature instability, which are known side effects of phototherapy, particularly with higher heat-emitting light sources like halogen lamps.

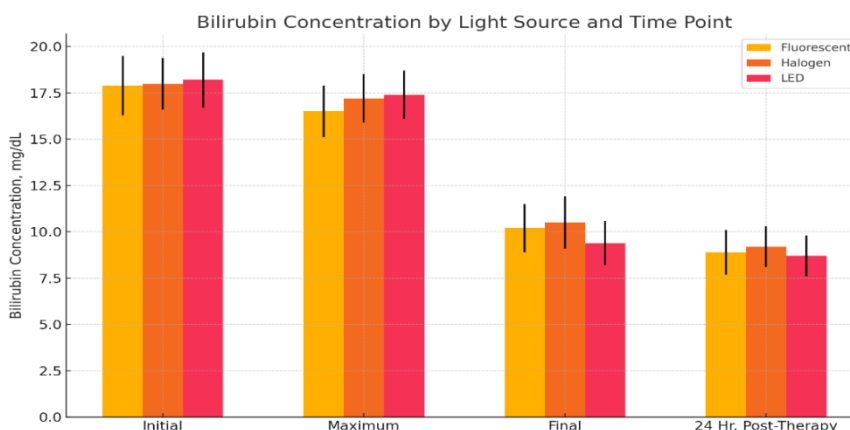


Figure 3. Bilirubin concentration by light source and time point

As shown in Figure 3, the bar chart comparing bilirubin concentration across different time points for the three light sources: fluorescent tubes, halogen lamps, and LED lamps. The error bars represent the standard deviations for each group. This chart visually represents the differences in bilirubin levels at various stages of treatment, helping to illustrate the effectiveness of each light source in reducing bilirubin levels in infants undergoing phototherapy.

The demographic parameters such as gestational age, infant age at treatment initiation, and gender distribution were similar across the groups, indicating that the randomization process was effective in creating comparable groups. The mean gestational age was approximately 38 weeks across all groups, and the mean infant age at the initiation of treatment was around 3 days.

4. Discussions

The findings of this study underscore the potential advantages of using LED lamps for the treatment of neonatal jaundice over more traditional light sources such as fluorescent tubes and halogen lamps. The LED group not only demonstrated a higher efficacy in reducing serum bilirubin levels but also required a shorter duration of treatment, which is clinically significant as it reduces the time the newborns are exposed to light therapy, potentially minimizing stress and discomfort. The superior performance of LED lamps can be attributed to several factors. LEDs emit light in a more specific wavelength range that is closer to the peak absorption spectrum of bilirubin, which likely enhances the photochemical reaction required to convert bilirubin into its water-soluble forms. This targeted wavelength, combined with energy efficiency and lower heat emission of LEDs, makes them an optimal choice for phototherapy. The reduced heat emission is particularly important in neonatal care, as it decreases the risk of hyperthermia and dehydration, common complications observed with other light sources, especially halogen lamps. The lower complication rate in the LED group further supports the safety profile of this light source. The complications associated with phototherapy, such as skin irritation and temperature instability, were less frequent in the LED group, suggesting that the lower thermal output of LEDs is less likely to cause adverse effects compared to halogen lamps, which emit more heat and are more likely to cause thermal stress to the infant.

The study's results aligned with previous research suggesting the benefits of LED phototherapy over traditional methods [24]. However, this study is particularly valuable as it was conducted in a specific clinical setting in Bahrain, providing locally relevant data that can inform healthcare practices in the region [25]. The findings could have significant implications for clinical practice, recommending a shift towards the use of LED lamps in neonatal jaundice treatment not only for their efficacy but also for their potential to improve patient safety and reduce treatment duration. The findings of this study are supported by a growing body of literature highlighting the advantages of LED phototherapy in treating neonatal jaundice [26]. Studies have consistently demonstrated that LED lamps, with their narrow spectral emission targeting the peak absorption range of bilirubin (around 450–460 nm), are more effective in reducing serum bilirubin levels compared to traditional fluorescent and halogen lamps.

For instance, a study [27] which emphasize that phototherapy devices incorporating narrow-band blue-to-green LED light (460–490 nm) with sufficient irradiance and maximal body surface area exposure are the most effective and safest for reducing bilirubin levels in neonates. Super LED phototherapy is significantly more effective than halogen phototherapy, reducing bilirubin levels faster (27.9% vs. 10.7%) and requiring shorter treatment duration (36.8 vs. 63.8 hours) [28]. A randomized trial [29,30], demonstrated that super LED phototherapy is more effective and safer than conventional triple fluorescent tube phototherapy for severe neonatal hyperbilirubinemia, achieving higher success rates in avoiding exchange transfusion (87% vs. 64%), faster bilirubin reduction, and fewer side effects such as hyperthermia, dehydration, and skin rash.

In terms of healthcare policy, the adoption of LED phototherapy units could lead to more cost-effective and sustainable healthcare practices. While the initial cost of LED units may be higher than that of fluorescent or halogen lamps, the long-term savings from reduced energy consumption, lower maintenance needs, and fewer complications could offset the initial investment. Additionally, enhanced treatment efficiency could free up NICU resources, allowing for better management of hospital capacity. This study provides compelling evidence supporting the use of LED lamps as the optimal light source for phototherapy in neonatal jaundice. The results not only contribute to the growing body of literature favouring LEDs but also offer practical recommendations for healthcare providers in Bahrain and similar settings, promoting better outcomes for newborns with jaundice. Future research could explore the long-term outcomes of infants treated with different light sources, as well as the cost-effectiveness of transitioning to LED phototherapy on a broader scale [31-33].

5. Conclusions

The present study provides strong evidence that LED lamps are the most effective and practical light source for the treatment of neonatal jaundice in a clinical setting. Among the three light sources evaluated LED lamps, fluorescent tubes, and halogen lamps, LEDs demonstrated superior performance in reducing serum bilirubin levels, with the shortest treatment duration and the lowest incidence of complications. Beyond their clinical efficacy, LED lamps also offer significant practical advantages, including higher energy efficiency, lower heat emission, and greater portability, making them particularly well-suited for resource-limited settings.

6. Future Recommendations

1. It is important to conduct multicenter trials involving a larger and more diverse population of newborns to confirm these findings and make them applicable to as many cases as possible.
2. The long-term effects of different light sources on newborn health, such as their impact on mental development and metabolic functions, should also be studied.
3. It is essential to evaluate the economic aspects and compare the costs of purchasing and maintaining LED phototherapy devices with those of conventional devices, especially in different healthcare settings.
4. We could also consider trials using combined or advanced light types, such as dual-wavelength or fiber optic systems, to improve bilirubin reduction outcomes.
5. We should not forget the importance of obtaining parents' and medical team's opinions on the use of LED devices, in terms of ease of use, safety, and their impact on daily workflow.
6. Finally, it is essential to develop clear guidelines and training courses to standardize the use, maintenance, and monitoring of LED phototherapy devices in neonatal care units.

7. What is already known about this topic?

Neonatal jaundice is a common condition, with phototherapy being the primary treatment since the 1950s. Traditional light sources, such as fluorescent tubes and halogen lamps, have long been used, while LED lamps have recently emerged as an alternative, offering potential advantages such as energy efficiency and reduced heat output.

Despite this, the optimal light source for phototherapy remains debated, with previous studies providing inconsistent evidence regarding their comparative efficacy.

8. What does this study add?

This study demonstrates that LED lamps are significantly more effective in reducing serum bilirubin levels, requiring a shorter treatment duration, and resulting in fewer complications compared to fluorescent tubes and halogen lamps. These findings provide strong evidence for the clinical and operational superiority of LED phototherapy, supporting their adoption in neonatal care to improve patient outcomes and resource efficiency.

These findings have important implications for clinical practice, suggesting that the adoption of LED phototherapy units could lead to better patient outcomes, enhanced safety, and more efficient use of healthcare resources. The study also aligns with broader healthcare objectives, such as the optimization of neonatal care and the implementation of cost-effective, sustainable medical practices. Given the compelling advantages of LED lamps observed in this study, it is recommended that healthcare providers consider transitioning to LED-based phototherapy for the management of neonatal jaundice. Future research should continue to explore the long-term outcomes associated with different phototherapy methods and evaluate the broader cost-effectiveness of implementing LED technology in various healthcare settings.

Declarations

Source of Funding

This study received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Competing Interests Statement

The authors declare that they have no conflict of interest.

Consent for publication

The authors declare that they consented to the publication of this study.

Authors' contributions

All the authors took part in literature review, analysis, and manuscript writing equally.

Availability of data and materials

Supplementary information is available from the authors upon reasonable request.

Institutional Review Board Statement

Not applicable for this study.

Ethical Approval

The study plan was reviewed and approved by the Research and Ethics Committee at King Hamad University Hospital (Approval Number: [RMS-KHUH/P&PEC/2023-700]).

Informed Consent

Written informed consent was obtained from the parents of all participating children after a full explanation of the study objective, procedures, and potential risks.

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